

National Bureau of Standards



April 1956
Volume 40
Number 4

Technical News Bulletin

Low-Temperature Alinement of Radioactive Nuclei

Provides data on nuclear disintegration

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APR 27 1956
DETROIT

LOW-TEMPERATURE research at the National Bureau of Standards has succeeded in alining the nuclei of three radioactive elements—cerium-139, cerium-141, and neodymium-147. These results were achieved by cooling samples of the three materials to within a few thousandths of a degree of absolute zero. At such temperatures the effects of thermal agitation become so small that atomic nuclei can line up in a given direction within the crystal lattice. A corresponding directional effect can then be observed in the emitted radiation.

The nuclear alinement experiments¹ were carried out by E. Ambler and R. P. Hudson of the Bureau staff in cooperation with G. M. Temmer of the Carnegie Institution of Washington. Initial phases of the work were sponsored by the Office of Naval Research.

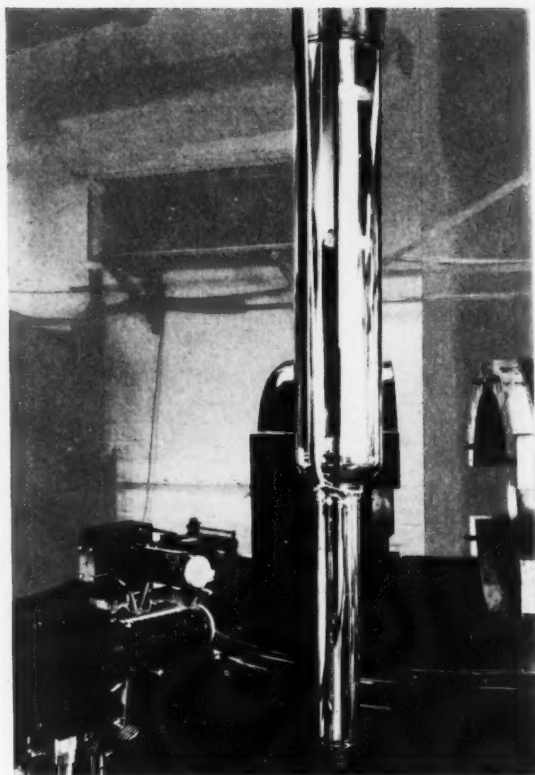
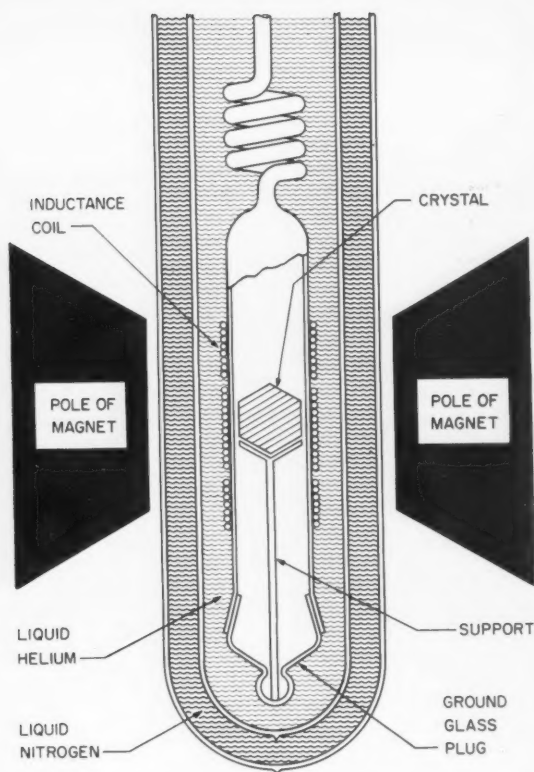
Low-temperature alinement of nuclei promises to provide a new tool for studying the processes of nuclear disintegration. The nucleus may be regarded as a magnetic top spinning about an axis. If this spinning magnet is radioactive, the orientation of the spin axis will determine the directions in which the nucleus emits radiation. Normally, when nuclei are randomly oriented, a radioactive specimen emits gamma rays with equal intensity in all directions. However, when the nuclei are alined, the intensity of gamma radiation varies with angle of emission. By measuring the de-

gree of this directional effect, valuable information can be obtained concerning the decay scheme of the nuclei and an insight can be gained into the mechanisms controlling such processes. For example, the magnetic moment of the nucleus can be determined as well as the changes in angular momentum accompanying the emission.

In the Bureau's experiments, radioactive nuclei were incorporated into certain inorganic crystals formed by the elements studied, which were then cooled to temperatures as low as 0.003° K. Nuclear alinement was observed by measuring the angular distribution of the intensity of the gamma radiation emitted by the crystals.

Inasmuch as the crystals used were paramagnetic, the necessary low temperatures could be conveniently produced by the method of adiabatic demagnetization. In this method a paramagnetic crystal is first magnetized by a powerful magnet. The resultant heat of magnetization produced in the crystal is removed from the system. Then when the magnetic field is turned off, the reverse effect occurs, and the temperature of the crystal falls to a very low value. The specimen soon begins to reheat, of course, but if due care has been taken to reduce heat leaks, the rate of heating is slow enough to allow time for measurements.

In the experiments a magnetic field of about 23,000 oersteds was used. A radioactive crystal containing



Apparatus used in aligning radioactive nuclei at temperatures near absolute zero. A thin glass tube supports the crystal specimen within a glass vessel containing a small amount of helium gas at low pressure (drawing). Liquid helium and liquid nitrogen baths protect the system from heat influx. When the insulated specimen is placed in the field of a powerful electromagnet (right background, photo), the heat of magnetization produced in the crystal is conducted through the helium gas to the liquid helium in the surrounding Dewar flask. This keeps crystal temperature from rising. The crystal is then isolated thermally by pumping away the gas in the inner vessel. Thus, when the magnetic field is removed, the crystal temperature falls considerably. The directional effect of nuclear alinement on the emitted gamma radiation can then be observed with two scintillation counters (lower left, photo).

the element under study was mounted on a thermally insulating support within a glass tube containing a small amount of "exchange gas" (helium at low pressure). The exchange gas provided thermal contact between the crystal and a surrounding bath of liquid helium boiling at about 1° K under reduced pressure. The liquid helium bath was protected against heat influxes by a Dewar vessel, which was in turn surrounded by liquid nitrogen.

When the magnet was switched on, the heat of magnetization was conducted from the crystal through the exchange gas to the liquid helium. This kept the temperature of the crystal from rising. The crystal was then isolated thermally by pumping the exchange gas away. Thus, when the magnet was turned off, the temperature of the crystal fell appreciably.

To observe nuclear alinement, the apparatus was then quickly moved into position between two scintillation counters, and the intensity of gamma radiation was measured along two different directions. As the crystal warmed up, a gradual decrease in the degree

of alinement was observed. Finally, when the temperature reached 1° K, the nuclei were again found to be randomly oriented. This process was repeated a number of times in order to provide sufficient data to reduce the effects of random variation. From the data, basic information was obtained on the nucleus and its radioactive decay.

During each run the temperature of the crystal was monitored. This was done by measuring its magnetic susceptibility, which had previously been determined as a function of temperature by other investigators.²

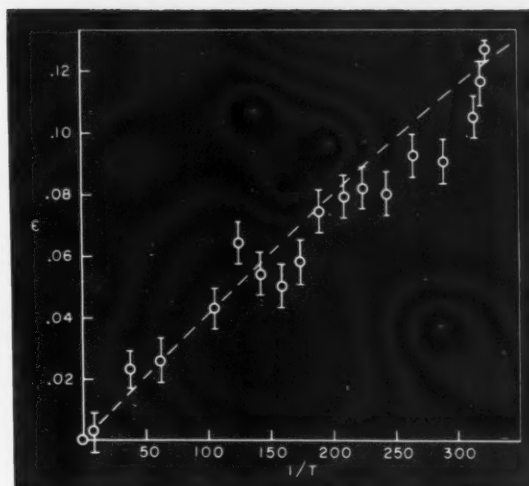
The physical processes that give rise to nuclear alinement may be described as follows. Interaction with the electric fields within the crystal causes the electronic magnetic moment of certain atoms to line up either parallel or antiparallel to a certain crystallographic direction. Then at very low temperatures, where thermal agitation is much less, the coupling between the atomic magnetic moment and the nuclear magnetic moment is strong enough to allow the nuclei also to be pulled into alinement. This coupling cannot begin to

Anisotropy (ϵ) of gamma radiation plotted against the reciprocal of absolute temperature for a radioactive crystal of cerium-141. Each point is the average of 10 demagnetizations. Short vertical lines show the spread of the data about each point.

overcome the forces due to thermal motion, however, until the temperature falls well below 1° K.

The anisotropic angular distribution of gamma rays from the aligned nuclei can be explained by considering angular momenta. Since the angular momenta of the parent and daughter nuclei as well as that carried away by the gamma ray are fixed by nature, it follows from the principle of conservation of angular momentum and from radiation theory that definite restrictions are placed upon the pattern of gamma-ray emission. The phenomenon is analogous to the radiation from a radio antenna, where anisotropic emission patterns are also observed. This close relationship between gamma radiation and angular momentum makes it possible to utilize gamma-ray intensity data as a basis for deductions concerning the angular momentum of the parent nucleus and the changes occurring during radioactive decay.

Work in this general field is continuing at the Bureau. Attention is now being directed to low-temperature methods of polarizing, rather than aligning, nuclei. Stable nuclei can be employed in experiments of this kind, and a larger number of different nuclei can be studied. The Bureau hopes to obtain additional data



of value to both cryogenics and nuclear physics.

¹ For further details, see Alignment of cerium-141 and neodymium-147 nuclei, by E. Ambler, R. P. Hudson, and G. M. Temmer, *Phys. Rev.* **97**, 1212 (1955); and Alignment of three odd-A rare earth nuclei, by the same authors, *ibid.* **101**, 1096 (1956).

² J. M. Daniels and F. N. H. Robinson, *Phil. Mag.* **44**, 630 (1953).

A Standard Gloss Scale for Porcelain Enamels

A SIGNIFICANT improvement in the stability and consistency of specular gloss measurements is made possible by a standardized method recently developed at the Bureau. Intended primarily for application to porcelain enamels, the method establishes sizes and tolerances for the critical geometric dimensions of specular glossmeters.¹ The resulting gloss scale, following a recommendation of the Porcelain Enamel Institute, closely approximates that of the widely used Hunter multipurpose reflectometer.

The task of determining the instrumental geometry required to duplicate the gloss scale of the Hunter reflectometer was undertaken by I. Nimeroff and H. K. Hammond, III, of the photometry and colorimetry laboratory, and J. C. Richmond and J. R. Crandall of the enameled metals laboratory. On the basis of their work, gloss tests for porcelain enamels have been included in the methods recommended by the Porcelain Enamel Institute and the American Society for Testing Materials.²

Gloss measurement in the past has been used principally to evaluate the resistance of high-gloss enamels to abrasion or chemical attack. Usually specimens are measured, before and after attack, on the same instrument in the same laboratory. The data thus obtained are useful for determining relative resistance to attack

even though a standardized gloss scale is not used. Serious difficulties arise, however, when one attempts to compare readings of nonstandard glossmeters in different laboratories. A further impulse toward standardization has come in the last few years from the development of porcelain enamels in a wide range of gloss. Used mainly for architectural purposes, these enamels make heavy demands on uniformity of product and matching of components made in different plants.

Specular gloss may be defined as the fraction of light flux reflected in the direction of mirror reflection (the specular direction) when the sample is illuminated by a parallel beam of light. In the case of enamels the angle of incidence (and reflection) is taken as 45°. When measuring the gloss of paints, an incidence angle of 60° is more common. If the fraction mentioned is multiplied by 1,000, the gloss is given in conventional "gloss units." For enamels, then, the specular gloss is the fraction of light energy, in parts per thousand, reflected at 45° when the specimen is illuminated at 45°.

Unfortunately, strictly parallel beams are not obtainable, nor can the light reflected in the specular direction be perfectly separated from that in adjacent directions. Bureau studies have shown that disregard of the effects of angular spread among the incident



Goniophotometer for measuring specular gloss of porcelain enamels and other ceramic materials. Light from within aluminum box near operator's hand goes through a rectangular window, is collimated, strikes the specimen (held vertically in frame at center of picture), and is reflected into the receptor arm at right. There the light is again collimated and goes through another rectangular window into the spherical integrating enclosure at extreme right of receptor arm. The operator is holding removable brass plate containing adjustable source window. The emf of the photocell in the integrating enclosure is measured by the galvanometer and slidewire potentiometer at lower left.

rays (aperture of the source) and among the reflected rays (aperture of the receptor) is largely responsible for the discrepant results obtained with different glossmeters.³

In practical glossmeters a beam of light issues from a source, falls on the specimen, and is reflected through a rectangular window into a receptor where its intensity is measured either photoelectrically or in some other manner. The source is oriented with its long dimension perpendicular to the plane of measurement, that is, the plane determined by a ray from the center of the source and the normal to the specimen at the point of incidence. Because the source is rectangular, the spread of light in the beam will vary in different planes through the optical axis. In this case it is customary to define the "aperture of the source" as the pair of angles that measure the spread in the planes perpendicular and parallel, respectively, to the plane of measurement. The long dimension of the receptor window is oriented like that of the source, and the "aperture of the receptor" is similarly defined as a pair of angles.

When the Bureau, acting on a proposal of the Porcelain Enamel Institute Quality Development Committee, took up the problem of glossmeter standardization, an instrument devised at the Bureau in 1936, the Hunter multipurpose reflectometer, was already in wide use and provided a convenient scale of values. Although sufficiently accurate for relative measurements on a single instrument, the glossmeter section of the Hunter reflectometer was designed before the importance of accurate control of field angle was appreciated. In general, therefore, its readings vary from one instrument to another. The problem then was to determine the geometric constants of a glossmeter having a scale similar to that of the Hunter instrument.

At first the possibility was considered of making a direct measurement of the geometry of a Hunter instrument. However, the complexity of the Hunter optical system made such a determination unfeasible. Instead, a special goniophotometer was used as a glossmeter, and its source and receiver apertures were adjusted by trial to duplicate the desired scale and thus to establish the geometry requirements.

The goniophotometer used had been constructed for earlier studies.³ It is basically a device for throwing a beam of light onto a specimen at any desired angle of incidence and for measuring the light reflected in any direction in the plane of measurement. Light is provided by a standard headlight bulb. Its filament is brought to a focus in the plane of the source window, which thus becomes the effective source. Light from the window is collimated by an achromatic lens before falling on the specimen. The reflected light goes through another achromatic collimating lens which, if the specimen had a mirror surface, would form an image of the source in the receptor window. Then the light enters an integrating sphere in which three photocells, connected in series, measure the total flux through the receptor window.

As space conservation was not a problem, the instrument was made sufficiently large to permit measurement of its components with high geometric accuracy. It is so constructed that one can control accurately and independently (1) both dimensions of the rectangular source and receptor windows, (2) angles of illumination and view, (3) beam collimation, and (4) position of source image relative to the receptor window.

One of the Bureau's Hunter instruments was chosen for comparative study. With it the gloss of nearly 100 specimens was measured. The instrument was set up in the usual manner with the gloss opening in a hori-

zontal position and a sample of appropriate reflectance in position to furnish the comparison beam. The gloss scale was adjusted for linearity by inserting calibrated neutral filters in the gloss beam in front of the receiver window.

Two fundamental considerations guided the trial-and-error process for determining the angular size of the goniophotometer source and receptor apertures that give readings in agreement with the Hunter multipurpose instrument. First, it was shown that glossmeter readings for highly diffusing (low-gloss) specimens are almost completely independent of the size of the source. Readings for such specimens are directly proportional to the angular size of the receptor entrance window, the cosine of the specular angle (in this case 45°), and the diffuse reflectance of the specimen. Thus a multipurpose-instrument gloss reading for a highly diffusing specimen of known reflectance permits calculation of the angular size of the receptor window of that instrument.

Second, readings for high-gloss specimens depend primarily on the size of the source relative to the receptor size. If the source is too large, reflected rays that should enter the receptor are blocked by the entrance window and a low reading results. If the source is too small, reflected rays that deviate too far from the specular angle are permitted to enter the receptor

Diagram showing essential components of the NBS goniophotometer used in standardizing specular gloss measurements of porcelain enamels.

and a high reading results. Therefore, once the receptor aperture had been chosen, the trials for determining the source aperture could be restricted to high-gloss specimens.

To minimize the work, a criterion on scale duplication was set. This criterion required that for the 100 specimens selected the gloss reading obtained on the adjusted goniophotometer should not differ generally from that obtained on the multipurpose instrument by more than 5 gloss units.

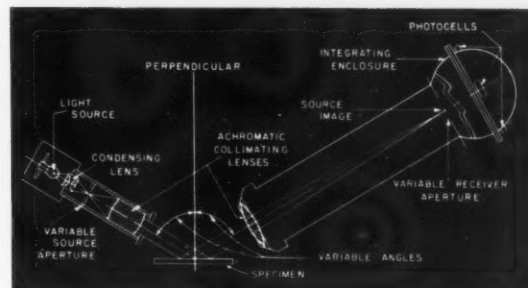
The dimensions of the rectangular source and receptor apertures thus determined were 2.7° by 1.8° and 9.9° by 7.9° , respectively. With slight modification and addition of tolerances, this glossmeter geometry was ultimately recommended to the Porcelain Enamel Institute and the American Society for Testing Materials for incorporation in their test methods.

TABLE 1. Recommended glossmeter apertures and tolerances, parallel and perpendicular to the plane of measurement, for 45° specular gloss of ceramic materials, PEI and ASTM test methods

Measurement plane	Aperture and tolerance	
	Source	Receiver
Parallel.....	deg. 1.4 \pm 0.4	deg. 8.0 \pm 0.1
Perpendicular.....	3.0 \pm 1.0	10.0 \pm 0.2

The receptor aperture was rounded off to whole degrees. With slight scale modification, the angular source size in the plane of measurement was reduced, and that perpendicular to this plane increased, to permit easier utilization of existing lamp filaments. Aperture tolerances were chosen partly on the basis of experience with similar tolerances for 60° specular gloss geometry and partly on the basis of the present investigation. The recommended glossmeter apertures and tolerances of the proposed methods are given in table 1.

It should be noted that specular gloss is but one of several factors that are related to the quality of gloss as perceived by the eye. Porcelain enamels happen to fall in the range, 1 to 100 gloss units, for which specular gloss correlates well with the perceived quality. For surfaces of lower gloss, however, such as paper and flat paints, the eye seems to be guided more by reflection at grazing angles and by the contrast between reflection in the specular direction and that in other directions. On the other hand, in the gloss range above that of the enamels, distinctness of images and absence of bloom or haze about them become the decisive factors influencing the visual judgment. Moreover, there are still other factors that must be taken into account in special situations.⁴



Also, in the specular gloss range, one can often distinguish the specular component in the reflected light from that which is diffused more or less uniformly in all directions. It is now generally considered desirable to correct measurements of specular gloss by subtracting the contribution made by the diffuse component, although so far only rough approximations to the magnitude of the latter are possible in most cases.¹

¹ For further technical details, see Specular gloss measurement of ceramic materials, by I. Nimeroff, H. K. Hammond, J. C. Richmond, and J. R. Crandall, *J. Am. Ceram. Soc.* **39**, No. 3 (March 1956).

² Gloss test for porcelain enamels, Bulletin T-18 of the Porcelain Enamel Institute: Tentative method of test for 45° specular gloss, ASTM designation C346-54T.

³ Measurement of sixty-degree specular gloss, by H. K. Hammond and I. Nimeroff, *J. Research NBS* **44**, 589 (1950) RP2105.

⁴ Methods of determining gloss, by Richard S. Hunter, *J. Research NBS* **18**, 19 (1937) RP958; Definition and measurement of gloss, by V. G. W. Harrison, *The Printing and Allied Trade Research Assoc.*, Cambridge, England, 1945.

Prelubricated Ball Bearings for Aircraft Use

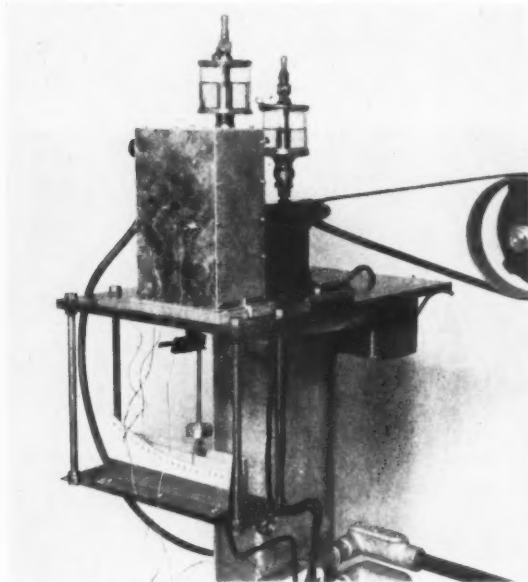
PPROMISING RESULTS have been obtained in trials of a method of prelubricating ball bearings. Incorporating a new application of felt pads, the bearings are intended for operation over the wide temperature range required for use in aircraft and at speeds up to about 10,000 rpm. The investigation, sponsored in part by the Navy Bureau of Aeronautics, included tests with different types of oil fortified with a variety of additives.

Prelubricated ball bearings, requiring no further lubrication during their normal life, may be used to advantage in many applications. Ball bearings prepacked with grease are often used, but are not entirely satisfactory, especially where speeds and temperatures are high. In aircraft equipment, for example, it is desirable to have bearings that will operate satisfac-

gested that felt rings, saturated with oil, be tried for bleeding oil to the bearings. In effect, the felt would be used instead of a soap or other thickener to supply oil slowly to the bearing, without further addition of oil to the felt.

In order to test this suggestion, metal holders for felt rings were designed so that such assemblies of holder and felt ring could be fitted to each side of a standard ball bearing. The felt-padded bearings were then subjected to a series of endurance tests in which the bearings were prepacked successively with a number of mineral and synthetic oils. The effect of various additives was also studied. All tests were run at 325° F and 10,000 rpm; and the bearings were mounted in a way similar to that used in the grease tests so that the results might be comparable.

No. 204 (SAE No. 20BC02) ball bearings with a 20-mm bore were used as the test bearings. Each was mounted outboard on a spindle which was supported in turn by two bronze journal bearings lubricated by sight-feed oil cups. The outer race of the test bearing is mounted in a cylindrical housing provided with removable bearing shields at each end. An auxiliary sleeve around the housing increases the radial load to



Machine for testing high-speed, high-temperature, oil-soaked felt pads for use in prelubricated ball bearings. Bearings are mounted within heated aluminum box (upper left) on the end of a spindle driven by a constant-speed motor. Attached to bearing housing is a pendulum (seen projecting below the platform), whose position on the scale indicates the frictional torque on the bearing.

torily over the temperature range from -65° F to +400° F. Conventional greases do not meet this requirement, chiefly because of excessive starting friction at the low end of the temperature range and poor stability at the high end.

In earlier studies an apparatus was developed for determining the frictional torque of ball bearings operating over a wide range of speed at high temperatures. In one phase of this work, endurance runs were made with several greases in ball bearings operating at 10,000 rpm. With this speed and at high temperatures, it was found that the greases that performed best were those that adhered to the outer race after being thrown from the path of the balls, and then lubricated the bearing by slow bleeding. This sug-

1,500 grams. High temperatures are maintained by two electric heaters mounted just below the housing.

A pendulum attached to the underside of the housing is used in conjunction with a calibrated scale for measuring the frictional torque. The lower end of the pendulum dips into a damping fluid in an open pan, for minimizing fluctuations. When the torque becomes abnormally high, the pendulum operates a switch to break the drive-motor and heater circuits, thus bringing the endurance test to an end.

The ring-shaped felt pads were made from 1/4-in.-thick felt. The pads were mounted in the annular grooves of the ring-shaped holders. Then they were immersed in the test oil at 340° F for a few minutes until bubbling ceased, removed, and allowed to drain. This treatment at high temperature was necessary to remove air, moisture, and other volatile matter from the felt. Otherwise, bubbling tended to remove most of the oil from the felt in the ball-bearing assembly during the first heating to 325° F.

For each test, a new ball bearing was cleaned with solvents, dried, dipped in the test oil at 340° F, and allowed to drain. The bearing was installed in a manner similar to that used for the greased bearings, but

with an oil-soaked pad on each side. The pads are so designed and positioned that the felt contacts the outer race but does not contact either the inner race or the ball separators of the bearing.

In general, operation was continued with 21 hours of running and 3 hours of shutdown each day; except that on weekends the operation was for about 28 hours followed by shutdown over the remainder of the weekend. Each test was continued until failure of the bearing, as evidenced by excessive torque which operated the automatic overload device.

The mineral oils used in these tests ranged in viscosity from a transformer oil to an SAE No. 60 motor oil. Some were straight mineral oils; others were of heavy-duty type containing oxidation inhibitors and detergents.

The synthetic oils included silicone fluids, polypropylene glycol derivatives containing oxidation inhibitors, and sebacates containing additives. In general, the samples of di(2-ethylhexyl) sebacate containing additives have pour points below -75°F and flash points above 400°F .

With di(2-ethylhexyl) sebacate containing no additive except an oxidation inhibitor, the length of the endurance test was only 48 hours. However, with the four samples (SO-11 to SO-14 of table 1) of this diester containing tricresyl phosphate, the length of test

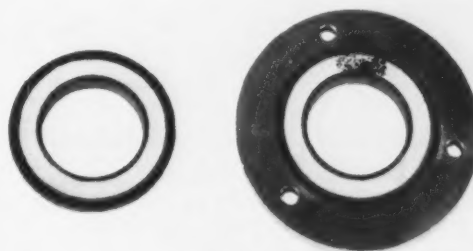
phate) increased the length of test to 1,781 hours. These results are consistent with the expected effect of the additives. Viscosity data for the sebacate samples, together with their endurance times, are given in table 1. In contrast with these results, conventional pre-lubricated ball bearings, filled with a typical prepacking grease, in three endurance runs under the same conditions, lasted only 178, 307, and 330 hours, respectively, before failure.¹

Of the various types of oils tested it is believed that the di(2-ethylhexyl) sebacate containing tricresyl phosphate and other appropriate additives is the most promising. In addition to its excellent performance at 325°F , its viscosity characteristics at low temperatures indicate that it would be the most suitable type for low-torque starting at -65°F .

The wool felts used in these tests became charred at 325°F , especially after operating over 1,000 hours. For operation at temperatures above 325°F it is possible that pads made from other fibers, such as metal, glass, or heat-resistant plastics, might be suitable.

Although the evidence is not conclusive, a number of trends are indicated by the data. First of all, under the conditions of these tests and when suitable fluids are

Felt pad, holder, and bearing shield for prelubricated ball bearings. At left, the white felt ring is shown fitted into annular groove of its metal holder. At right, holder has been snapped into its metal shield. The prelubricated ball bearing is mounted between two such assemblies as that on right.



before failure was over 1,000 hours. Sample SO-11 is the reference oil given on page 3 of Military Specification MIL-L-7808. Samples SO-12 to SO-14 are essentially this reference oil with other additives designed to increase its load-carrying performance at high temperatures. The average length of tests before failure with the four samples of the diester containing tricresyl phosphate is greater than for any of the other types of oil tested.

Although the number of tests are too few to be conclusive, the addition of the viscosity index improver to sample SO-11 apparently increased the length of test from 1,005 hours to 1,246 hours, and the further addition of a mild extreme-pressure additive (acid phos-

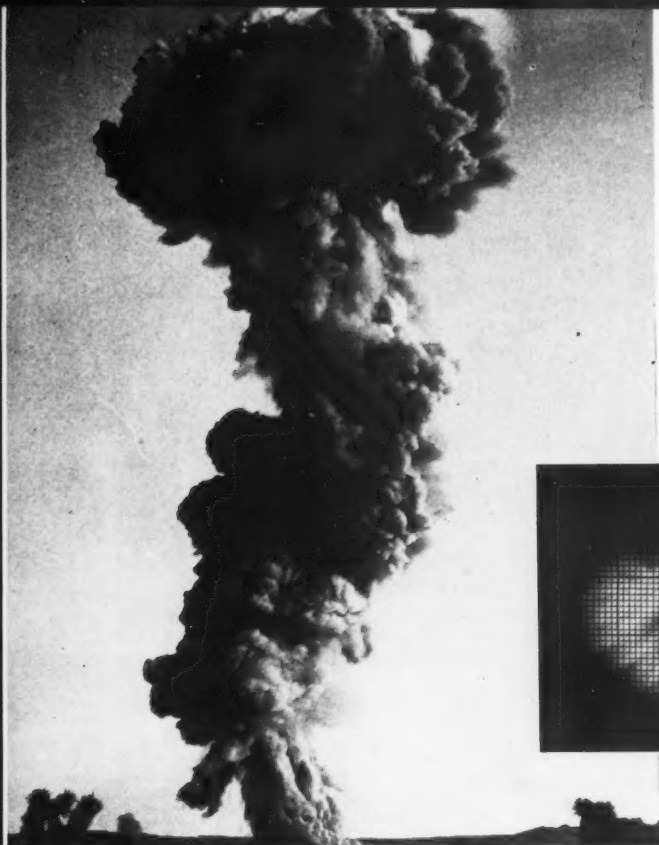
used, the oil-soaked felt-pad method of lubricating ball bearings shows promise of being superior to the practice of prepacking with grease. Then, as to the fluids, it appears that a low-pour-point mineral oil, such as transformer oil, is not suitable for operation at 325°F because of its high volatility at that temperature. On the other hand, there seems to be no advantage in using an oil higher in viscosity than an SAE 20 grade for the lubrication of ball bearings at high speed and temperature. Di(2-ethylhexyl) sebacate shows promise of furnishing satisfactory long-time lubrication at 325°F , provided it contains suitable additives. Of these additives, those of the mild extreme-pressure antiwear type, such as tricresyl phosphate, appear to be very effective.

A new series of experiments, under the sponsorship of the Navy Bureau of Aeronautics, is now under way. These experiments are expected to throw additional light on the above conclusions and possibly also to yield further results.

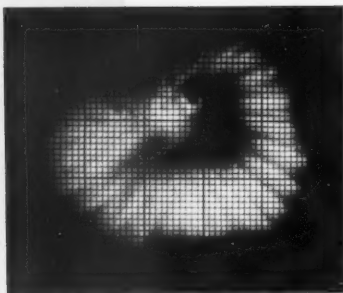
TABLE 1. Endurance times and viscosity data for di(2-ethylhexyl) sebacate samples

Sample code No.	Type of oil	Viscosity centistokes		Hours run before failure
		at 100°F	at 210°F	
SO-10	Di(2-ethylhexyl) sebacate.....	12.7	3.3	48
SO-11	SO-10+5% TCP.....	12.7	3.3	1,005
SO-12	SO-11+4% VI improver.....	22.5	5.6	1,246
SO-13	SO-10+TCP+other additive.....	14.0	3.6	1,498
SO-14	SO-12+4% VI improver+0.5% acid phosphate.....	43	10	1,781

¹ Further technical details are given in Oil-soaked felt-pad lubrication of ball bearings at high speed and high temperature, by H. S. White, J. F. Swindells, and Harriet F. Belcher, *Lubrication Eng.* 11, 182 (May-June 1955).



Radioactive Fallout Computer



Personnel safety is an important factor in atomic testing. A new analog computer displays pattern of radioactive fallout from bomb. Map on a transparent backing can be laid over pattern, and radioactive intensity can be determined at any point up to 500 miles from ground zero. The computer was adjusted to produce this apparent "fallout" without knowledge of the characteristics of any actual bomb, hence the pattern is not representative. Explosion photograph courtesy Atomic Energy Commission.

A SPECIAL-PURPOSE computer that gives the geographical fallout pattern of radioactivity resulting from a nuclear explosion has been developed by the National Bureau of Standards. Given the necessary weather data together with certain information about the bomb, this analog computer will assist in predicting what the distribution and intensity of radioactivity will be on the ground after the bomb has been detonated. Problem solution is displayed on a cathode-ray tube, over which a map on a transparent backing can be laid. Radioactive intensity at any ground point up to 500 miles from the explosion can then be measured by the brightness at the corresponding point on the tube screen. The computer was developed for the Weather Bureau and the Atomic Energy Commission by H. K. Skramstad and J. H. Wright of the analog computers laboratory.

Safety is a prime consideration at nuclear bomb testing grounds. Precautions are taken before a test to prevent radioactive material from falling on inhabited areas. Such precautions require information about the bomb as well as an intimate knowledge of the weather pattern, and from these data extensive calculations determine the fallout pattern. In the past, fallout predictions have required the laborious hand calculations of a team of mathematicians for $\frac{1}{2}$ hour or more for each prediction. The use of high-speed electronic digital computers eliminates most of the manual effort and reduces the calculation time to 15 minutes. However, these high-speed computers are usually large,

permanent, and expensive installations. To provide even faster predictions with portable, relatively inexpensive equipment, the Bureau developed a special-purpose computer that does not require highly-trained personnel for its operation. The machine uses electronic analog techniques to complete the computation almost instantly after the data are inserted. Subsequent changes in weather data can easily be inserted into the machine as rapidly as the operator can set the appropriate knobs.

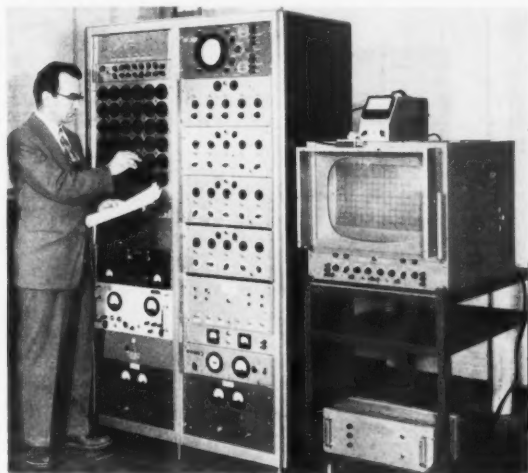
In its use at an atomic proving ground the new computer will provide the test manager with immediate knowledge of the effect of any changes in the winds. For civil defense, the computer can be used in research studies or in case of an actual attack. Forecasting could be expected to help determine and speed up the emergency procedures to be used after a bomb explosion, with a consequent saving in lives.

The prototype computer is contained in two 6-ft relay racks, including power supplies and one oscilloscope. A 21-in. display oscilloscope is mounted separately. About 106 tubes and 58 silicon junction diodes are used in the equipment, excluding power supplies and oscilloscopes. The total power requirement is about 1,500 watts. Data are fed into the machine simply by adjusting approximately 30 knobs on the front panel; 40 of these knobs correspond to wind speeds and directions.

While this is not a simulation analog computer, it uses analog techniques to mechanize the fallout problem.

In particular, time in this computer is used for sequencing only and has no direct significance in terms of the time variable in the original physical model.

A number of simplifying assumptions, based on past experience, are customary in computing fallout. They are considered to be reasonable and have been incorporated into the design of the computer. One assumption is that the distribution of winds is constant over the entire fallout area and does not change during the fallout period. Vertical components of the wind are neglected. The mushroom cloud resulting from the nuclear explosion is assumed to have a circular cross section that varies with height in some specified manner. Within the cloud is a distribution of particles of varying size and radioactivity. At any one height, this distribution is assumed to be uniform and to have circular symmetry. A further assumption is that no diffusion occurs during fallout, so that particles originating within any specified layer of the cloud maintain their relative positions.



For the problem solution, the cloud is divided into 20 horizontal layers at graded intervals of altitude so that a particle of typical size spends equal time falling through successive layers. The time required to fall through a layer is represented by a "slowness" generator in the computer; "slowness" here is the reciprocal of velocity. If the initial height from which a particle starts its journey and the wind direction and velocity in each layer are known from weather data measurements, it then becomes possible to predict the final landing position of each particle. Further information on the varying amount of radioactivity associated with the different particles in the cloud will give a measure of the radioactive distribution when the particles have fallen.

The computer obtains the ground coordinates and radioactivity intensities of all the particles by producing continuously varying voltages proportional to the slowness of the particles and to the height intervals, by scanning these voltages over the full ranges of the variables, and simultaneously developing the corre-

sponding fallout positions and intensities as voltages. The position voltages deflect the beam of a cathode-ray oscilloscope, and the radioactivity voltage modulates the intensity of the beam. The display on the cathode-ray tube then provides a map of the fallout of the radioactive dust while the luminance (brightness) of the tube represents the total intensity of fallout at any geographical location.

To take into account the diameter of the cloud, the spot on the cathode-ray tube must be effectively enlarged to have a diameter proportional to that of the cloud, depending on the height interval being considered during the changing state of the problem solution. The spot is spread sufficiently by generating a high-frequency spiral.

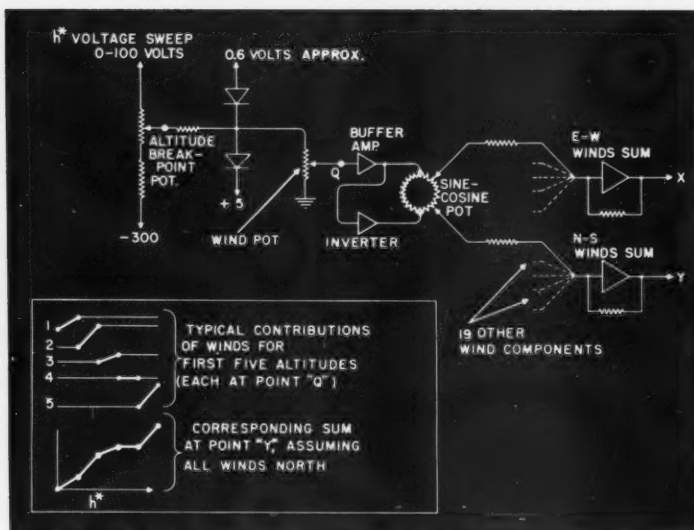
A height sweep unit within the computer produces a sawtooth voltage rising linearly with time, repeated 20 times per second. This 20-cps repetition rate is the basic cycle of the whole computer operation, and the entire problem solution is completed once each cycle. The sawtooth voltage is applied to the winds unit, which in turn produces voltages proportional to the *x*- and *y*-components of the displacement of a "standard" particle—one having unit fall time—as affected by the magnitudes and directions of the various winds. The winds unit contains 20 channels, one for each cloud layer. The outputs are fed into two summing units to

Special purpose computer developed for predicting the geographical fallout pattern resulting from a nuclear explosion. The analog computer gives distribution and intensity of radioactivity on the ground, after information on the weather and the bomb characteristics is fed in. Fallout pattern appears on oscilloscope screen.

generate voltages corresponding to north-south or east-west displacements of the particles. The height sweep voltage is also applied to the computer's cloud diameter generator.

A second sawtooth voltage is generated by a particle slowness sweep unit. This unit scans through the range of particle sizes twice while going through each cloud layer. The amplitude of this sweep is then modulated in one of the particle slowness modulators by the output from the winds unit. The effect is to multiply each component of displacement of the standard particle by a suitable scaling factor of slowness in order to modify this displacement for other particle sizes. In this computer no conventional multipliers are necessary, because the effect is achieved by a voltage-controlled sweep amplifier whose polarity is determined by the wind pattern. The outputs from the modulators are voltages proportional to the ultimate north-south and east-west positions of various-sized particles characterized by specific slowness and heights of origin.

A radioactive generator unit receives height sweep and slowness voltages as inputs, and produces a function of these two independent variables as an output. This output modulates the electron beam of the cathode-ray tube to produce an instantaneous screen brightness proportional to the instantaneous value of the radioactivity.



Simplified schematic diagram of one of the 20 channels in the "winds" function generator. This generator sums up the effects of the wind directions and speeds at 20 different altitudes.

Radioactivity at any ground location is generally the result of contributions from several parts of the cloud: light particles from the "far" side of one cloud layer may overlap heavier particles from the "near" side of some higher cloud layer when dust is deposited on the ground. Hence, the defocused cloud raster (the spiral) on any elementary area of the cathode-ray screen will have an overlap from some or many contributions of beam current during other phases of the problem solution.

The computer incorporates a means for adjusting the scale of the geographic map. It can be altered by the operator to read from 100 to 500 miles full scale. "Ground zero" can be shifted as desired, in case the fallout is mainly in one direction.

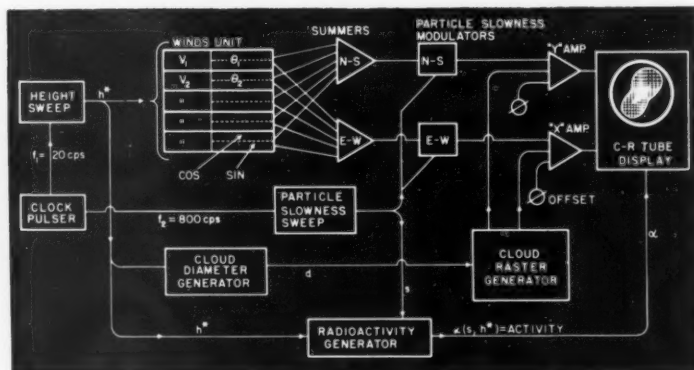
The computer is calibrated by inserting a simple standard problem, and adjusting the average luminance of the screen and the radioactivity scale factor to the most accurate readings on a photometer for both low- and high-level areas of luminance. When a real prob-

lem is fed into the machine, the photometer then reads directly either dose rate or total dosage, depending on how the operator chooses to set up the radioactivity generator.

The relationships between beam current, exposure time, and phosphor decay are quite complicated, and errors to be expected from the cathode-ray tube are difficult to predict. However, the first check problem run on the computer—before its actual completion—indicated a reasonably accurate prediction of fallout. The instantaneous display provided by the cathode-ray tube has been considered essential to the development of this computer. However, later models may eliminate the tube, in which case the geographical presentation will be printed out by means of an electric typewriter.

For further technical details, see An analog computer for radioactive fallout prediction, H. K. Skramstad and J. H. Wright, *Proceedings of the National Simulation Conference, Dallas, Texas, January 21, 1956* (in press).

Block diagram of the radioactive fallout computer. Information on wind direction, wind velocity, and cloud diameter at 20 different altitudes is combined with data on radioactive particle size and distribution to present a geographical pattern of the fallout.

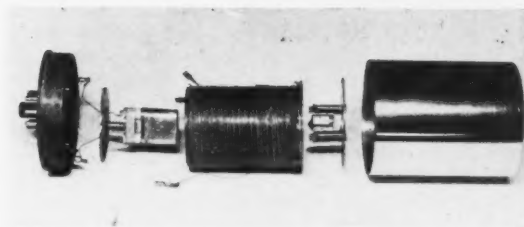
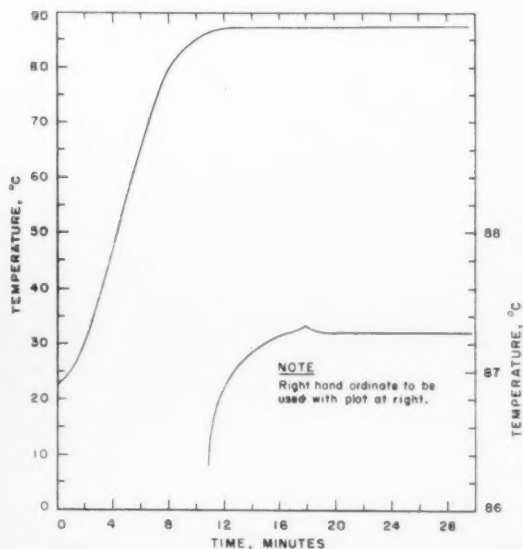


Constant-Temperature Oven for Quartz Crystal Oscillator

THE BUREAU has developed a simple, compact oven that stabilizes the temperature of a quartz crystal for precise oscillator frequency control. This oven utilizes the heat of fusion of an extremely pure organic compound—*p*-dibromobenzene—to hold the oven temperature within 0.01 degree of 87.31° C. Power requirements are low: 10 watts for normal operation and 20 watts during the brief warmup period. The instrument was developed for the Army Signal Corps by R. Alvarez and C. P. Saylor of the pure substances laboratory.

Quartz crystals are widely used as frequency standards, as filters in receiver circuits, and as frequency stabilizing elements in oscillator circuits. As a temperature change in a crystal will produce a change in its frequency, common practice has been to control the temperature of the crystal in precise frequency applications. Such close temperature control is usually achieved only by relatively large and complex systems. The special-purpose oven eliminates the need for much of the complex, bulky equipment ordinarily used.

Although the Bureau's instrument was designed specifically as a quartz crystal oscillator oven, it can be applied wherever a simple, compact thermostat for close temperature control is required. It can, for example, provide a constant temperature for a reference thermometer for extended temperature measurement and control. The oven uses *p*-dibromobenzene in its particular application, but other substances with different melting points provide other operating temperatures. Phenoxybenzene, for instance, has been employed in maintaining quartz crystals at a constant temperature of 26.88° C where the ambient temperature is low.



Unassembled view of constant-temperature oven that stabilizes the temperature of a quartz crystal for precise oscillator frequency control. Parts (r to l) housing; can, switch, heater, wire, crystal holder, and octal socket.

When a substance is partially molten, its latent heat of fusion provides thermal ballasting. That is, a heat loss causes crystallization of the material with evolution of the latent heat of fusion. A heat gain, on the other hand, results in absorption of heat as the solid phase melts. The melting temperature at the solid-liquid interface remains unchanged, provided that the material is pure and that the pressure is constant. A substance used for temperature control in this way must possess (1) a melting temperature within the desired operating limits, (2) chemical stability when in contact with oven components, (3) a high heat of fusion, and (4) a high velocity of crystallization. *p*-Dibromobenzene meets these requirements.

The oven is contained in a cylinder 3 $\frac{1}{32}$ in. high and 2 $\frac{11}{32}$ in. in diameter, mounted on an octal base. Inside the oven is a vacuum-tight container into which a quantity of *p*-dibromobenzene has been sealed. During operation of the oven, the material is about half liquid and half solid, and completely fills the container. At the top of the container is a metal bellows that is linked to a spring-loaded miniature switch. The volume changes occurring during phase transformations are transmitted to the bellows, turning a heater on or off to keep the chemical partially molten. Spring-loading the switch provides a pressure relief system in case a greater proportion of liquid is formed during the warmup period than would be present at the normal operating point. A second heater provides rapid warmup. It is controlled by a bimetallic element that cuts off the power when the substance is about 7 degrees below the melting point. A copper vane system distributes that heat rapidly throughout the container and reduces any temperature gradients that might exist if solid and liquid become separated during operation. The crystal and its holder fit into a well within the container.

Temperature stability data on the instrument were obtained by fastening a calibrated thermistor to a dummy crystal inside the crystal holder. The total temperature variation during a 6-day period of continuous operation did not exceed 0.007 degree C.

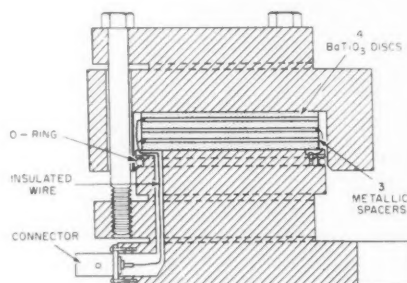
Time-temperature curve of oscillator crystal oven as it warms up and stabilizes its temperature. Total variation during 6 days operation did not exceed 0.007° C.

Meter for Shock-Velocity Measurements

A BARIUM-TITANATE velocity meter has been developed for use in shock-damage tests aboard moving ships or planes. Unlike most instruments used in such tests, the device has a sensitive axis which can be used at any angle without adjustment. Other design features include a uniform velocity response down to 1 cps and practically an unlimited displacement range. Development of the velocity meter was carried out by T. A. Perls¹ and C. W. Kissinger² under a program of basic instrumentation sponsored at the Bureau by the Department of Defense and the Atomic Energy Commission.

The use of velocity meters has become common in recent years for both vibration and shock measurements. Large velocity meters weighing up to 60 pounds are in common use, particularly for shipboard tests. Manufacturers of aircraft and shipboard equipment also make use of such devices to determine the shock-performance characteristics of their products. For these applications, velocity records are preferred to displacement or acceleration records because peak velocity correlates best with damage.

The basic element of the shock-velocity meter consists of 4 barium-titanate transducers which produce an electrical signal when a mechanical shock is imparted to the instrument.



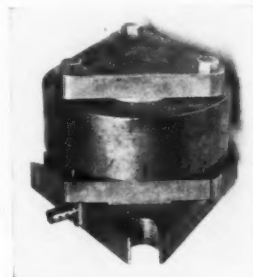
Development of the barium-titanate velocity meter was undertaken to overcome certain deficiencies of meters in present use which measure shock velocity directly. These velocity meters consist of a heavy mass spring mounted to a rigid frame attached to the test structure. When the test structure and frame are accelerated, the mass remains fixed in space for a small fraction of the natural period of the spring-mass system. As a result, during this short time interval, the displacement of the mass relative to the frame is equal (and opposite) to the "absolute" motion of the frame.³ This relative motion causes a pickup coil to cut the lines of force of a constant magnetic field, so that a voltage is generated. The voltage is proportional to the relative velocity between the mass and the frame (or the test structure), and therefore, for a limited time, is proportional to the "absolute velocity" of the frame.

These velocity meters are somewhat limited in operation because of certain inherent defects. They have a limited displacement range, because of the finite travel the sensing element is allowed, and an undesirable low-frequency resonance, typically between 3 and 5 cps.

Also, it is necessary to adjust or control the position of the element at the start of the motion. Under some conditions, particularly on a rolling ship, such an adjustment can be made only approximately. Finally, large errors may be introduced in the spring-mass system if the instrument is used with its sensitive axis other than vertical. To overcome these difficulties, the Bureau has developed the barium-titanate velocity meter operating on a different principle; this device is essentially an integrating accelerometer.

The sensing element in the Bureau's velocity meter is a group of four barium-titanate piezoelectric transducers, each 3 in. in diameter and 1/8 in. thick. This type of transducer is able to convert mechanical energy into electrical energy, or vice versa. The sensitivity of the device is such that an applied acceleration of one gravity unit (*g*) will produce an electrical output of approximately 200 millivolts. Linear range of the instrument is at least ± 300 *g*.

The acceleration output from the barium-titanate element must be integrated to obtain a velocity signal. To do this, a simple RC integrator may be used. In a



typical arrangement a velocity sensitivity of 4 mv/ft/sec is available at the amplifier recorder.

As this velocity meter is used below its resonant frequency, it is desirable to make this factor as large as possible. The resonant frequency of the present meter (unmounted) is 6,900 cps with commercially flat crystals. When optically ground crystals were used, it was possible to increase the resonant frequency to 10,200 cps.

To achieve the highest possible resonant frequency, the velocity meter base, the barium-titanate disks, and the loading mass must be in contact over their entire mating surfaces. The assembly then acts as a compression spring. To accomplish this the force exerted by the bolts that hold the assembly together must be applied in such a way that the surfaces that bear against the barium-titanate disks are not distorted. In the present instrument, good contact was established by machining three "ears" on the loading mass and on the base, and providing an undercut. Thus, the force exerted by the three assembly bolts is applied relatively uniformly around a circle of smaller diameter than that of the barium-titanate disks.

When the device is mounted on a heavy object, the theoretical resonant frequency should be 0.7 times the unmounted resonant frequency. This assumes perfect coupling between the velocity meter base and the surface to which it is mounted. It was found that such a coupling is obtained, for practical purposes, by means of a lead mounting shim, $\frac{1}{16}$ in. thick, between the base and the mounting surface. Contrary to expectations, it was found that the lead shim did not flow sufficiently under compression to reduce the compressive force appreciably over an arbitrarily selected time interval of 6 days.

The effect of the inherent temperature sensitivity of the barium titanate is reduced to negligible proportions in the instrument by minimizing both radiation and conduction heating of the sensitive element. This is

accomplished by enclosing the instrument in a housing to promote temperature equilibrium between the element's surfaces.

This accelerometer can conveniently produce shock-damage data that were previously unavailable because of measurement limitations. It is expected that these data will lead eventually to design changes and improvements in the shock-load performance of aircraft and shipboard equipment.

¹ Now at the Missile Systems Division, Lockheed Aircraft Corp., Van Nuys, California.

² Now at the Naval Ordnance Laboratory, White Oak, Maryland.

³ Evaluation of selected shock instruments, by T. A. Perls and H. L. Rich. Report 720, February 1951, The David Taylor Model Basin, Washington 7, D. C.

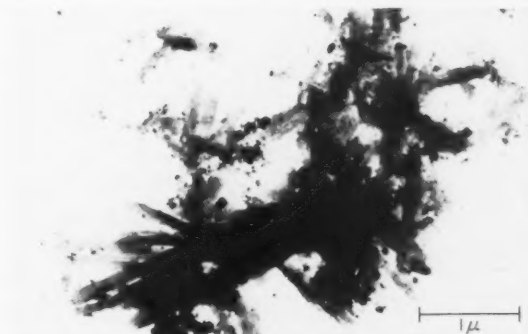
Zinc Oxide-Eugenol Dental Fillings

DEEP DENTAL cavities have long been treated with a mixture of zinc oxide and eugenol. This white, puttylike material relieves toothache and acts against bacteria in a tooth cavity. However, quality control of such fillings has been largely a matter of experience gathered in practice over the years. Little has been known about the actual reaction taking place between the zinc oxide and eugenol—whether it is, for example, a true chemical reaction or a physical process like hydration. Because scientists did not know the precise nature of the reaction, it has been difficult to predict, much less accurately control, such things as setting times, hardness, and strength of the hardened product.

The dental research laboratory therefore began an investigation of zinc oxide and eugenol mixtures. The study, sponsored by the armed services' dental corps and the American Dental Association, has shown that a chelate compound is formed by these materials.¹ The compound produced, zinc eugenolate, absorbs any unreacted materials to form a hardened mass of remarkable stability. The investigations were made by H. I. Copeland, Air Force guest worker; G. M. Brauer and W. T. Sweeney of the Bureau; and A. F. Forziati, Research Associate, American Dental Association.

Chelate compounds are cyclic compounds which are formed by a coordination process, in this case with a zinc ion. Most chelates are remarkably stable. In the case of zinc oxide and eugenol, long, thin crystals are formed. The crystals act as a matrix for the set mass and absorb any unreacted material. The reaction is thus both a chemical and a physical process.

The Bureau made use of several modern techniques in its study of zinc eugenolate. Chemical procedures coupled with X-ray diffraction measurements were employed. The infrared absorption spectra of zinc eugenolate were compared to those of another chelate compound, zinc quinolate, since information with respect to the latter's structure was available from recent studies elsewhere.² For further comparison, guaiacol and the zinc oxide-guaiacol reaction product were employed.



Electron micrograph shows how thin, elongated crystals of the chelate compound (zinc eugenolate) act as matrix for small particles (zinc oxide) and absorb unreacted material.

Elementary analysis and molecular-weight determinations established the empirical formula of zinc eugenolate as being $(C_{10}H_{11}O_2)_2Zn$.

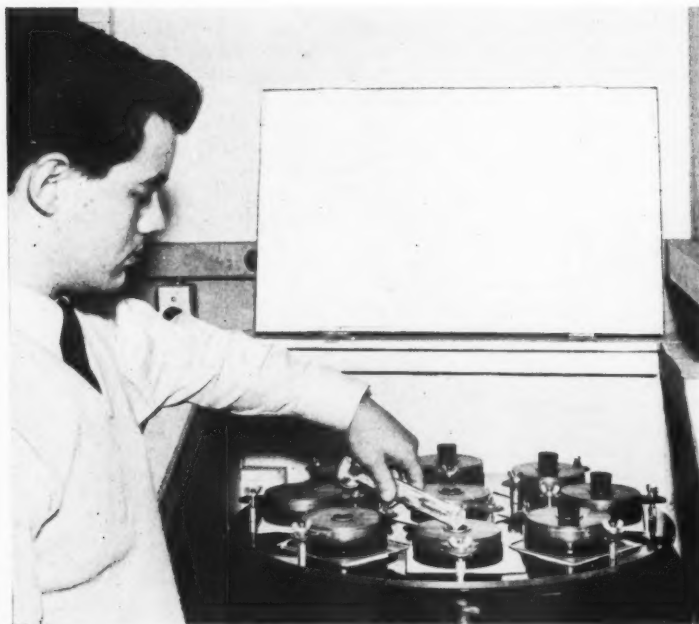
With the information that a chelate compound is formed by zinc oxide and eugenol, it is possible to predict other materials that will form like compounds for dental use. The Bureau has produced similar chelate compounds for study, using guaiacol and methyl guaiacol as chelating agents. Such agents must have a replaceable hydrogen and a nearby donor group. Mixtures of zinc oxide and liquids such as phenol or veratrole cannot harden (form chelate compounds) because they do not have the required molecular structure.

Having described the reaction, the Bureau plans to compile further data on various chelate compounds and their ingredients so that the mixtures used in dental fillings may be directly controlled. Present studies in this area include determinations of the required amount of surface activity of the zinc oxide employed, optimum amount of water, mixing temperatures, and kind and amount of fillers.

¹ For further technical details, see Setting reaction of zinc oxide and eugenol, by H. I. Copeland, G. M. Brauer, W. T. Sweeney, and A. F. Forziati, *J. Research NBS* **55**, 133 (1955) RP2611.

² L. Merrit, Jr., *Anal. Chem.* **25**, 718 (1953).

Abrasion Testing Machine for Porcelain Enamels

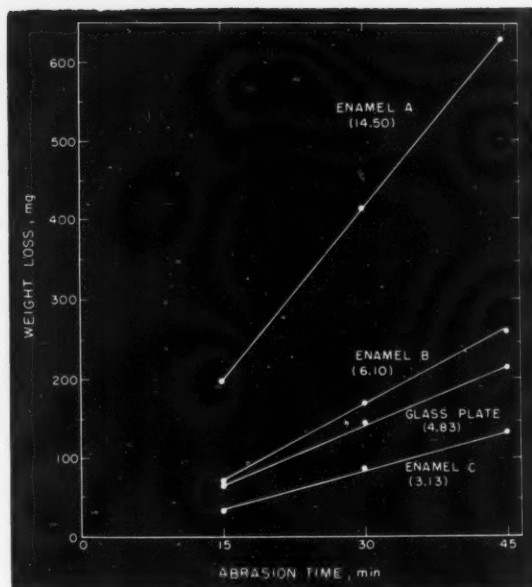


Abrasion tester developed for determining the abrasion resistance of porcelain enamels and other materials. Instrument provides a rapid, reliable method for testing enamels having different types of finishes, including "orange peel" and wavy surfaces.

A SIMPLE, rapid device for determining the abrasion resistance of porcelain enamels has been developed at the Bureau. The instrument provides a reliable means for testing enamels having different types of finishes, including "orange peel" and wavy surfaces. While the abrasion tester was designed primarily for porcelain enamels, it can be used for determining the wear resistance of such other materials as highway paints, plastic and fibrous materials, and organic finishes. The instrument and test method were developed for the Porcelain Enamel Institute by its Research Associates at the Bureau, George Warren and J. H. Giles.

Abrasion resistance is one of the most important factors in the service performance of protective coatings. Floor coverings are subjected to scuffing, and enameled sinks and cooking utensils are frequently scoured with cleansing powders containing fine abrasives. As all enamels are not equally resistant to abrasion, techniques for predicting the service behavior on the basis of laboratory measurements are of considerable value to porcelain-enamel manufacturers. The Bureau, in cooperation with the Porcelain Enamel Institute, has been working for a number of years on the development of suitable methods and instruments for testing surface coatings. The most recent result of this work is the abrasion tester.

The instrument consists essentially of a motor-driven table gyrating in a horizontal plane at 300 rpm. The



Curves illustrating relationship between weight loss and abrasion time for three porcelain enamels and a glass plate studied in the abrasion tester. Numbers in parentheses are the slopes in milligrams per minute. Each curve is almost a straight line; for porcelain enamel this relationship holds until the enamel is penetrated and the underlying ground coat or base metal is exposed.

table moves parallel to itself, and describes a circle $\frac{7}{8}$ in. in diameter. It is driven by a $\frac{1}{4}$ -hp synchronous motor, and testing time is accurately controlled by an electric timer. Nine specimens, $4\frac{1}{2}$ in. square, can be fastened to the table for simultaneous testing.

A specimen is placed in one of the nine available positions on the table and secured with a rubber-coated aluminum retaining ring. An abrasive charge consisting of 3 g of abrasive grit, 175 g of stainless steel balls ($\frac{5}{32}$ -in. diam), and 20 ml of water is poured into an accessory hole in the top of the retaining ring. The apparatus is then set to oscillate for the required time. The effectiveness of the abrasive is increased by the motion of the steel balls on the moving specimens.

Two test methods have been devised, one for determining surface abrasion resistance and the other for subsurface abrasion resistance. The surface abrasion test is used when appearance is the main consideration, but the subsurface test method is followed when protection of the underlying metal is the more important.

Publications of the National Bureau of Standards

Journal of Research of the National Bureau of Standards, Volume 56, No. 3, March 1956 (RP2656 to RP2663 incl.). Annual subscription \$4.00.

Technical News Bulletin, Volume 40, No. 3, March 1956. 10 cents. Annual subscription \$1.00.

Basic Radio Propagation Predictions for June 1956. Three months in advance. CRPL 139. Issued March 1956. 10 cents. Annual subscription \$1.00.

Research Papers

Journal of Research, volume 56, number 3, March 1956. Single copies of the Journal vary in price. Single copies of Research Papers appearing in the Journal are not available for sale. The Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., will reprint 100 or more copies of a Research Paper. Request for the purchase price should be mailed to that office.

RP2656. Penetration of gamma radiation from a plane mono-directional oblique source. Martin J. Berger.

RP2657. A re-entrant cavity for measurement of complex permeability in the very-high-frequency region. R. D. Harrington, R. C. Powell, and P. H. Haas.

RP2658. Fundamental factors controlling electrical resistivity in vitreous ternary lead silicates. Simon W. Strauss, Dwight G. Moore, William N. Harrison, and Lloyd E. Richards.

RP2659. Some factors affecting the precision of polarographic half-wave potential measurements. John K. Taylor and Stanley W. Smith.

RP2660. Infrared measurements from 50 to 125 microns. Earle K. Plyler and Nicolò Acquista.

RP2661. Surface tension of molten glasses in the system barium oxide-boric oxide-silica. Herman F. Shermer.

RP2662. Relationship between crystal orientation and stress-corrosion cracking in alpha and beta brasses. Hugh L. Logan.

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C568. High-temperature reactions of uranium dioxide with various metal oxides. S. M. Lang, F. P. Knudsen, C. L. Fillmore, and R. S. Roth. 20 cents.

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BMS144. Supplement. Sound insulation of wall, floor, and door constructions. Richard V. Waterhouse. 5 cents.

In the first method, Pennsylvania glass sand, between 70 and 100 mesh, is used in the abrasive charge, and the test is run for 5 min. The specular gloss is measured before and after the test, and the percentage retained gloss at 45° is the surface abrasion index.

For determining subsurface abrasion, a coarse fused alumina grain is used for the abrasive grit, and the test is operated for 45 min. The slope of the portion of the abrasion-time-weight-loss curve between the 15- and 45-min points is taken as the abrasion index. The specimen is weighed at the end of each of three 15-min abrasion periods; a fresh charge is inserted at the beginning of each period.

Tests of several porcelain enamels in the abrasion tester at four cooperating laboratories have led to the conclusion that the two test methods give satisfactory reproducibility. Results of the experiments show that the indices of abrasion resistance assigned to the various enamels are in general agreement with service experience.

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TECHNICAL NEWS BULLETIN

U. S. DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, *Secretary*
NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, *Director*

April 1956 Issued Monthly Vol. 40, No. 4

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Subscription price, domestic \$1.00 a year; 35 cents additional for foreign mailing; single copy, 10 cents. The printing of this publication has been approved by the Director of the Bureau of the Budget, March 6, 1953.

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Patents

(The following U. S. Patents have been granted to NBS inventors. Assigned to the United States of America, as represented by the Secretary of the Department noted in parentheses.)

- No. 2,727,000 December 13, 1955. Concentration of uranium isotopes by molecular distillation of uranium polyalkoxides. Aubrey K. Brewer, Samuel L. Madorsky, and T. Ivan Taylor. (AEC.)
- No. 2,728,717. December 27, 1955. High-vacuum distillation apparatus. Samuel L. Madorsky. (AEC.)
- No. 2,731,875. January 24, 1956. Polarimeter. John H. Gould. (Commerce.)
- No. 2,732,900. January 31, 1956. Selective multiple punch for card perforating. Jacob Rabinow. (Commerce.)
- No. 2,732,985. January 31, 1956. Electrolyte filling device and method for reserve type primary batteries. Paul L. Howard. (Navy.)

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